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Prior Models on Coronary Arteries to Support Coronary Artery Detection

Paper Review Presentation

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Project Overview

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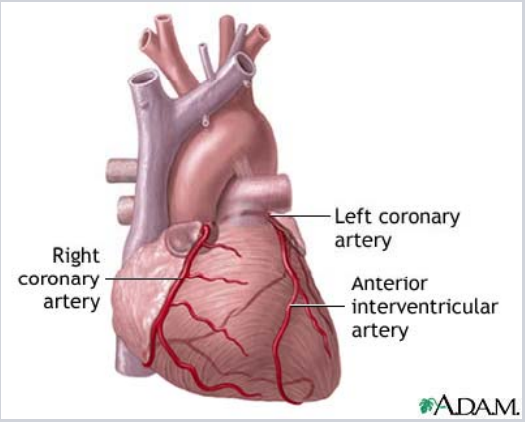
Coronary Artery Disease

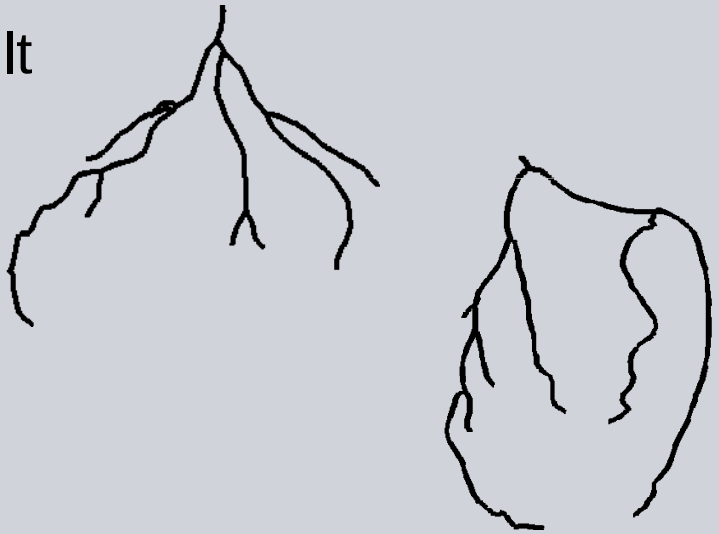
- 53% of cardiovascular diseases. Leading cause of death in the United States!
- Coronary detection in CTA is important for diagnosis, treatment and monitoring.



nlm.nih.gov

Problem: Coronary detection from CTA is difficult due to

- their high anatomical variability
- pathologies and imaging artifacts



Project Goal: Build prior coronary models to

- improve detection
- allow for statistical analysis

Technical Approach

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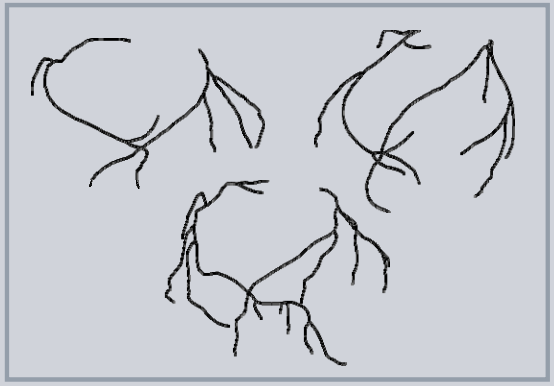
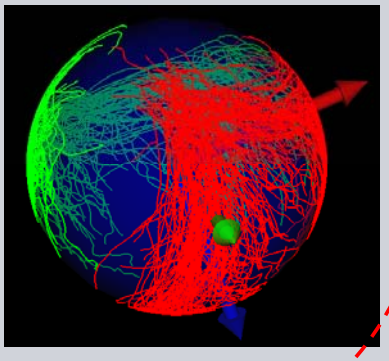
50 CTA coronaries



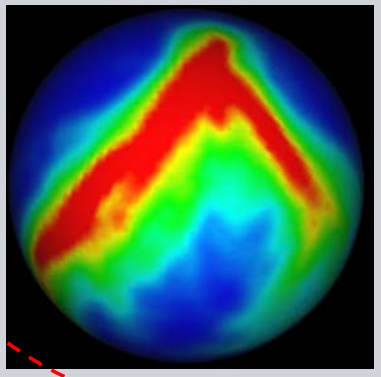
M1

Alignment

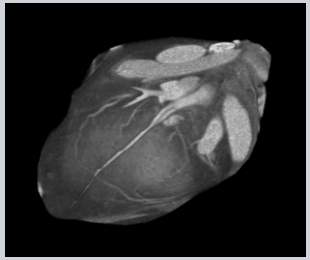


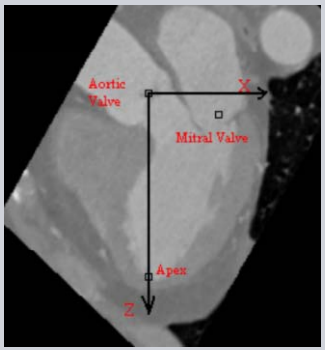
M2

Statistics on Territories



Coronary Density Map





M3

Coronary Tree Matching

TED metric

M4

QED metric

M5

Average Tree

Paper Selection And Relevance

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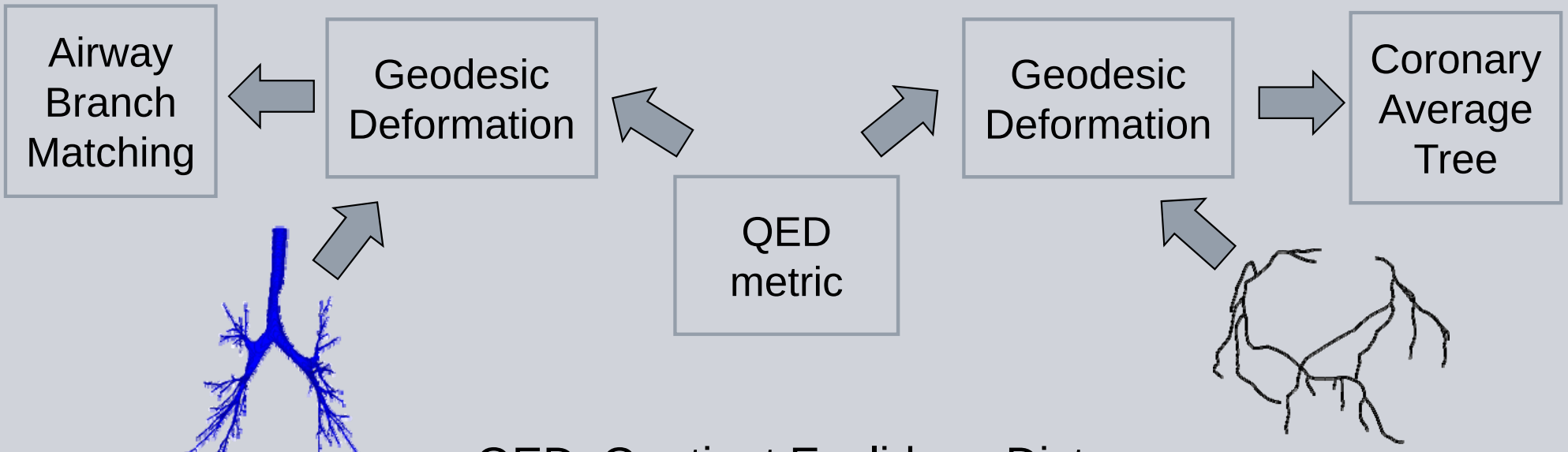
"An airway tree-shape model for geodesic airway branch labeling"

A. Feragen, P. Lo, V. Gorbunova, M. Nielsen, A. Dirksen, F. Lauze, and M. de Bruijne. An airway tree-shape model for geodesic airway branch labeling. In *Third MICCAI Workshop on Mathematical Foundations of Computational Anatomy*, 2011.

Relevance to my project:

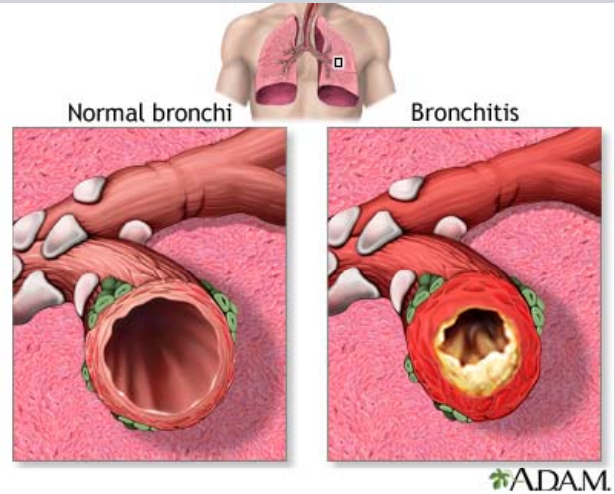


Feragen et. al.

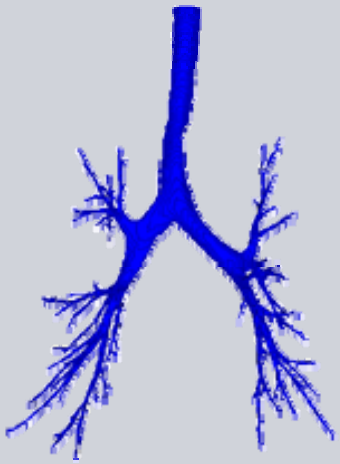
QED: Quotient Euclidean Distance

Problem Statement

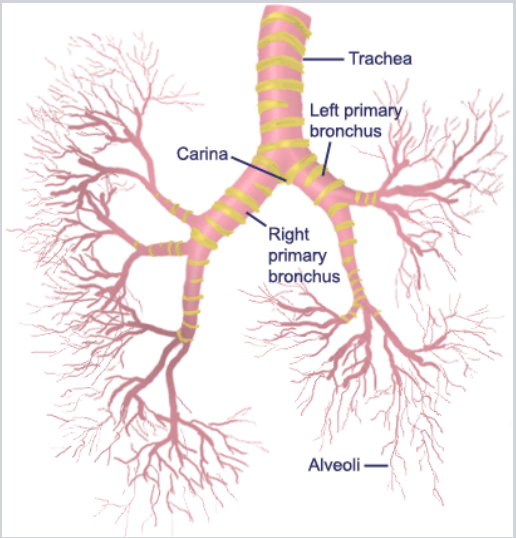
- Diseases related to airway properties
  - ➢ Chronic Obstructive Pulmonary Disease
- Monitor disease progression
  - ➢ variation of airway properties at specific sites
  - ➢ need for airway tree correspondence between two subjects



- Airway tree shapes for correspondence
  - ➢ extracted in CT scans
- Difficult problem due to
  - ➢ spurious or missing branches
  - ➢ anatomical variability



Feragen et. al.



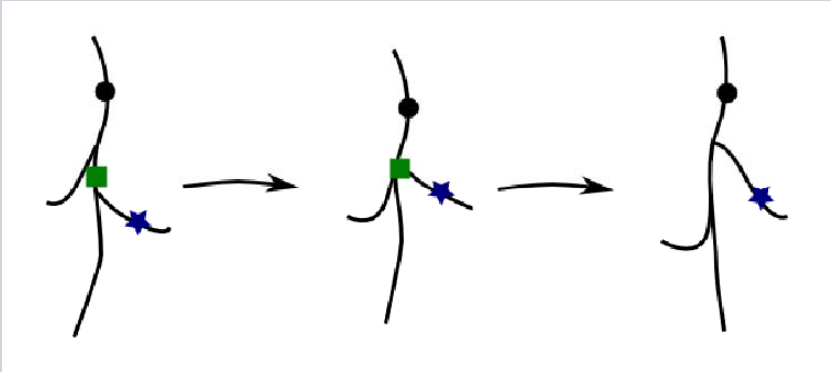
McGill University

Background

Methods using either topology or branch shape

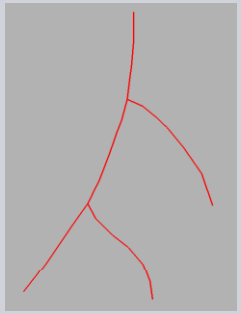
- Maximal cliques on association graphs
  - ➢ Only topology, NP-hard
- Recursive labeling
  - ➢ prone to topological order of branches
- Path matching
  - ➢ looses topological information, no branch matching

- Method proposed in this paper
  - ➢ based on both topology and branch shape: main contribution
  - ➢ continuous geodesic deformation



Feragen et. al.

Method – Geometric Space



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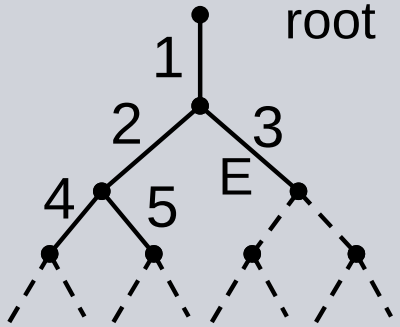

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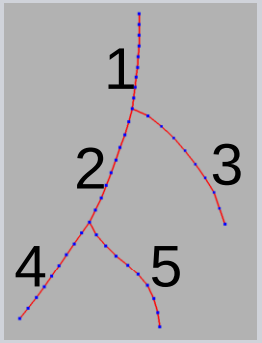
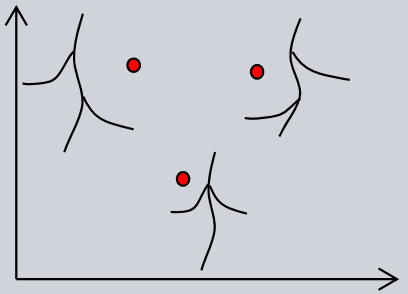


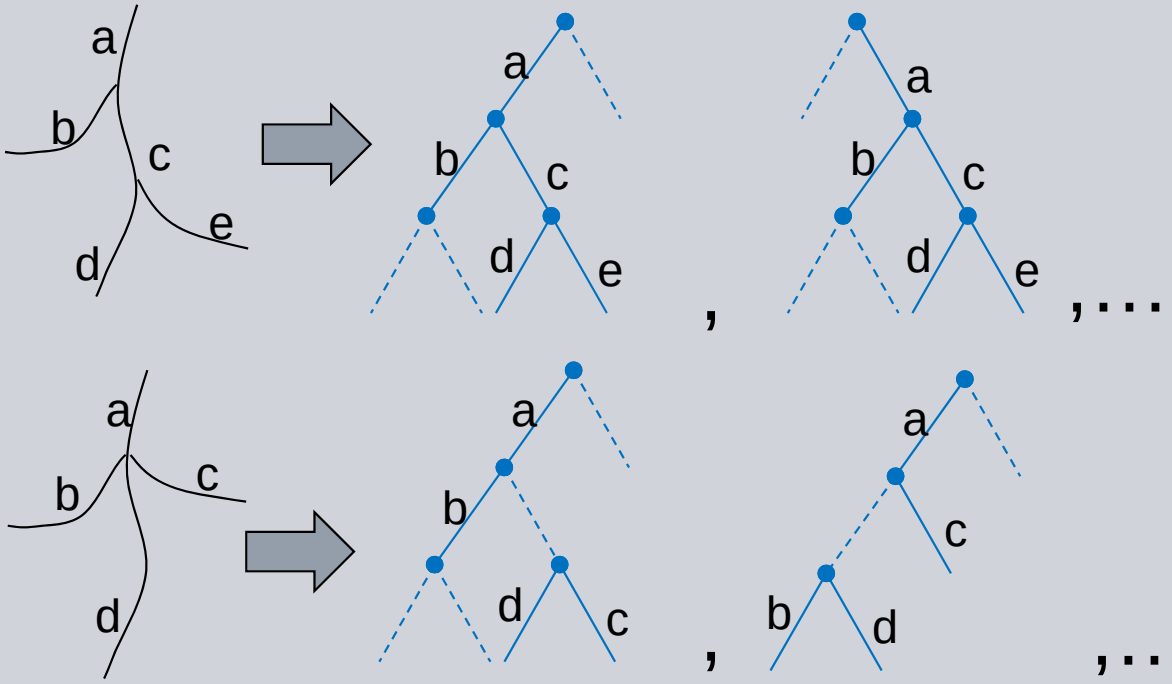


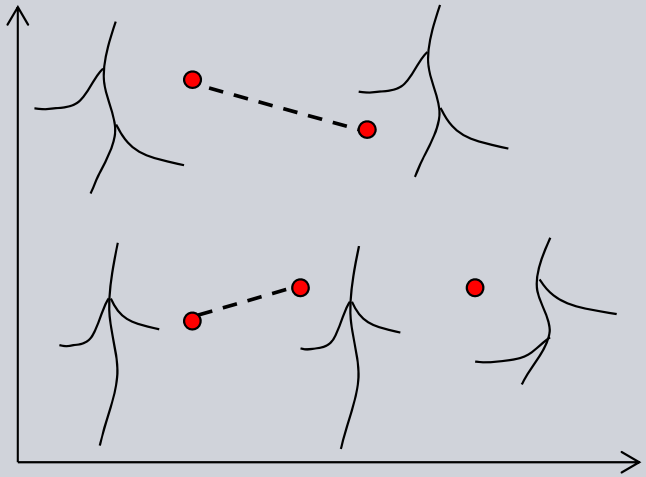
Tree-shape space

f:branch attribute, n: landmarks

$f : E \to \mathbb{R}^{3n}$

$X = \prod_{e \in E} \mathbb{R}^{3n}$

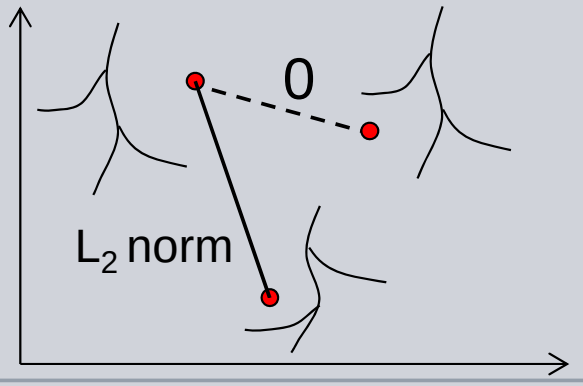




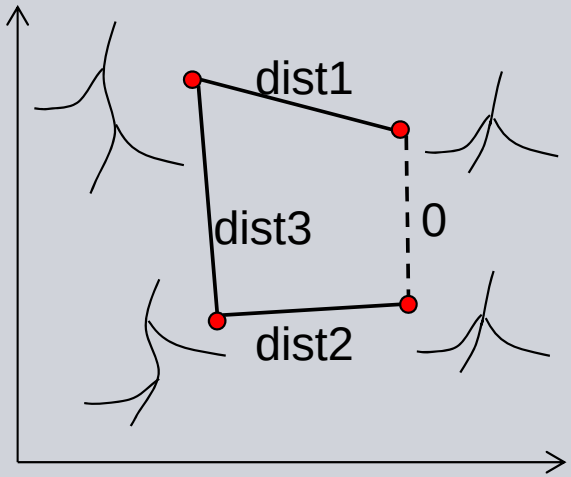
Quotient Space $\tilde{X}$

Method – Quotient Euclidean Distance

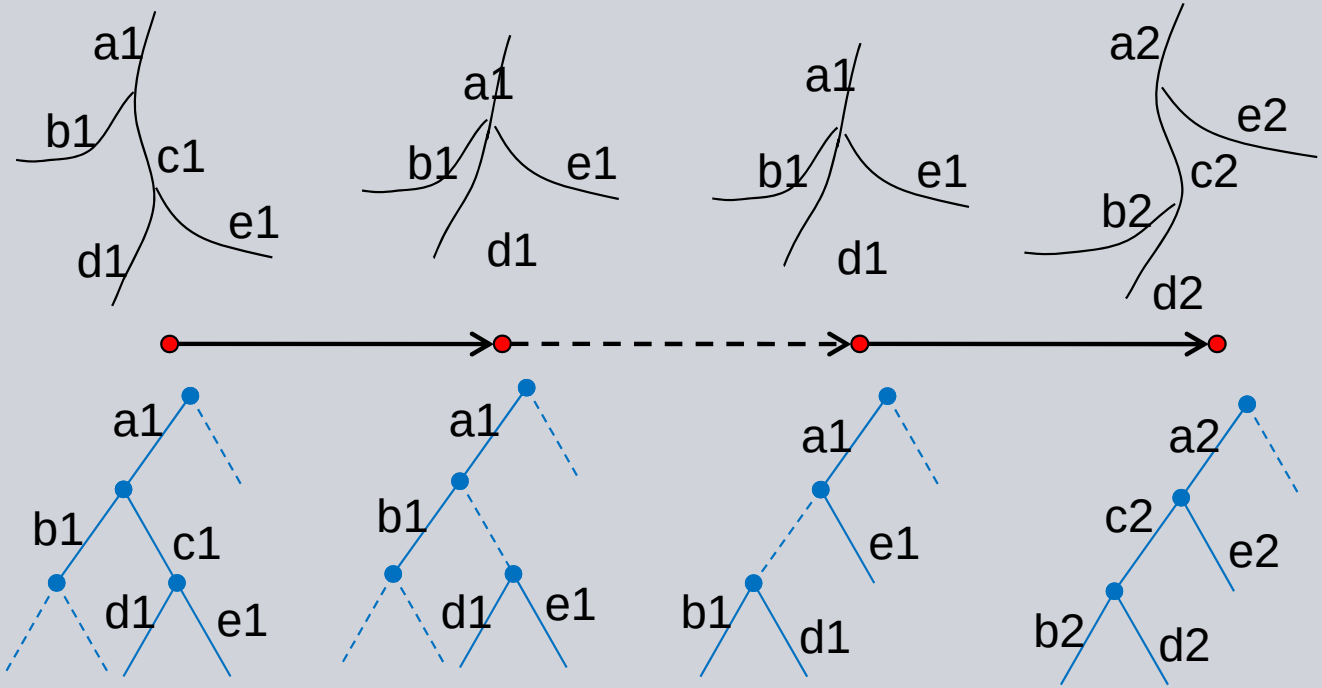
- Euclidean distance in the quotient space $\tilde{X}$
  - L_2 norm between nonidentical trees
  - 0 between identical trees



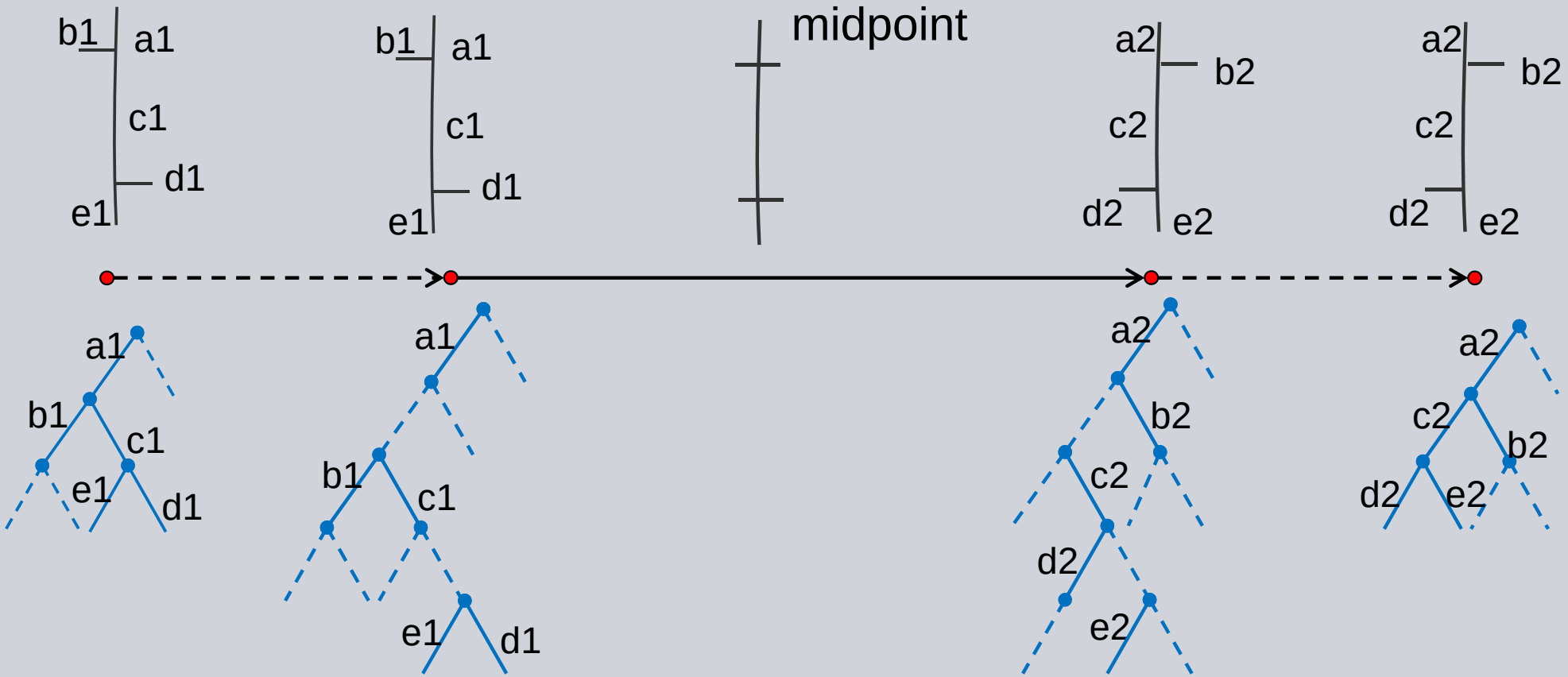
- Geodesic path: a series of internal structural changes with minimum cost



dist1 + dist2 < dist3!



Method – Quotient Euclidean Distance



- Unique Geodesic Path with L2 norm metric
  - ➢ Well suited for registration and statistics
- L1 norm ⇨ Same geodesic distance as TED (Tree Edit Distance)

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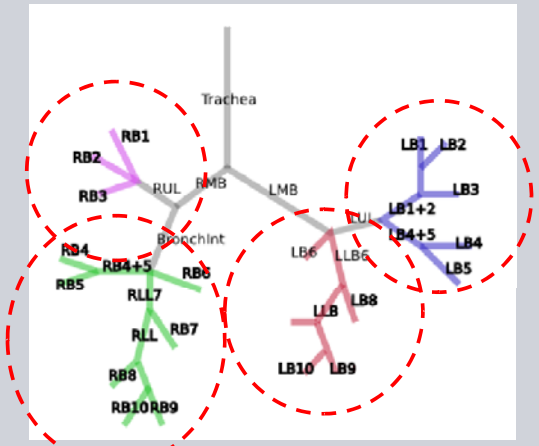
Method – Application to airways

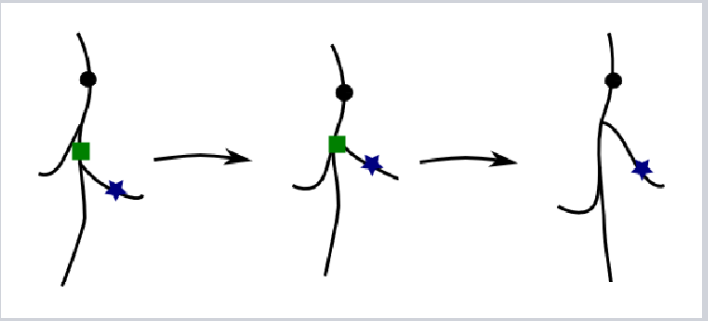
- Airway tree shapes are in 3D and
  - ➢ branch orders unknown
- Consider all orders
  - ➢ computationally expensive
  - ➢ match each lobe separately



Feragen et. al.

- Implementation: consider all possible paths and take the shortest path
  - ➢ too many paths!
  - ➢ put an upper bound on internal changes

- Propagate branch labels through deformation
- Majority vote
  - ➢ propagated labels from multiple trees



Feragen et. al.

Experiments

- Airway centerlines from 20 EXTRACT'09 segmentation challenge data
- Labels by trained image analyst
- 6 landmarks sampled along each branch, short ones were pruned
- Each tree was normalized by the size of LMB branch
- 6 main branches were fixed and method was run on 5 lobar trees separately
- Branches down to 6-7 generations considered
- Only one internal topological transition was allowed in the deformation
- Airway trees were matched with a leave-one-out fashion
- Branches with less than 55% consensus or 4 votes were discarded

Results

CASE	21	22	23	24	25	26	27	28	29	30
% correct	75	88.2	92.9	80	77.8	86.7	88.9	94.4	66.7	89.5
# correct	12	15	13	12	14	13	16	17	14	17

CASE	31	32	33	34	35	36	37	38	39	40
% correct	90	76.5	88.9	100	83.3	78.9	66.7	80	30	76.5
# correct	18	13	16	13	15	15	12	8	4	13

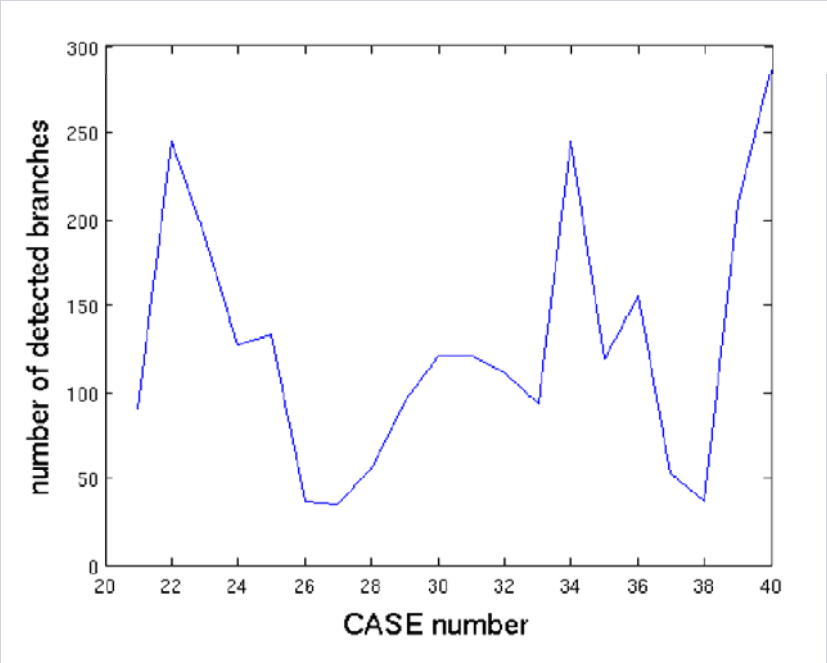
Feragen et. al.

- Average labeling success rate: 83%
- Authors opinion: Success rate was high taking the variation into account
- Comparison to other methods (with 97%, %90 success rates) was not possible because of different datasets used

Critique - Cons

- Authors claim: 83% is high given the large variation in topology

- Plot supporting their claim:



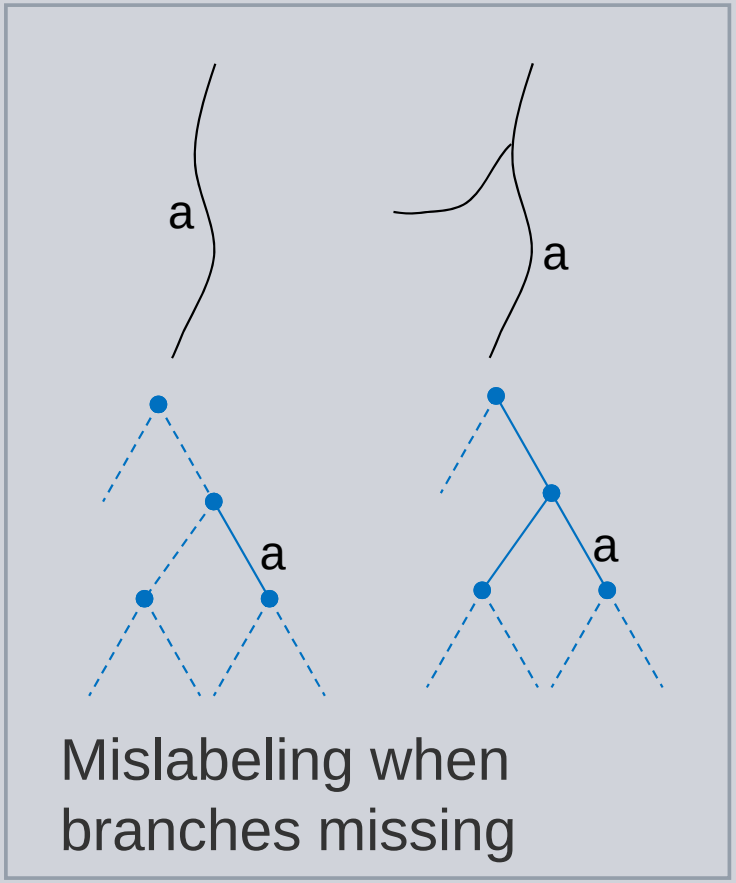
Feragen et. al.

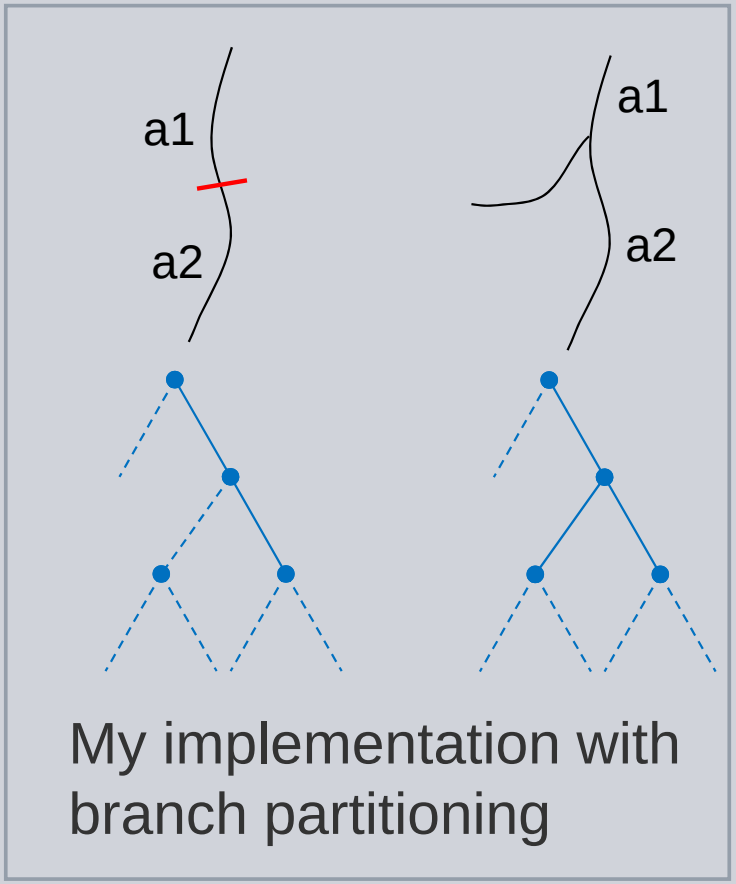
- But they run their method down to 6 generations

  - ➢ a similar plot for only down to 6 generations would be more supportive!

Critique - Cons

- Authors statement: airways trees may have missing branches





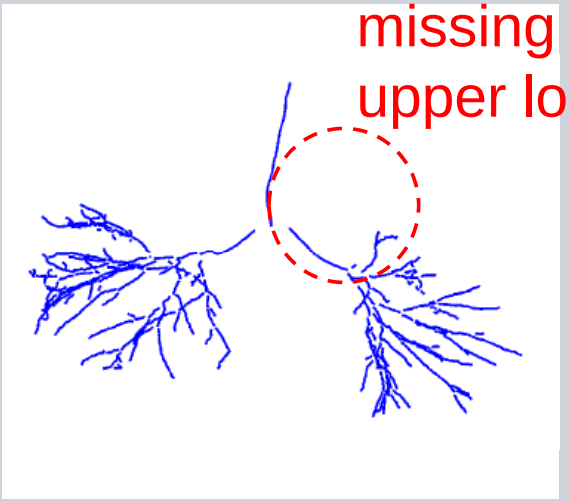
Critique - Cons

- Airway trees were normalized using LMB branch length
- No comment on the variability of LMB branch relative to airway tree
  - ➢ does larger airway trees always have longer LMB branch?
- In my project, coronary trees normalized relative to heart size
  - ➢ acceptable

Critique - Cons

- Were fixed branches included in the results?
  - ➢ if so, what are the results for only lobes?

- Authors claim: 30% accuracy in CASE39 was due to missing upper lobe
  - ➢ each lobe was matched separately
  - ➢ why other lobes were affected?



CASE39 Feragen et. al.

- no clue about runtime

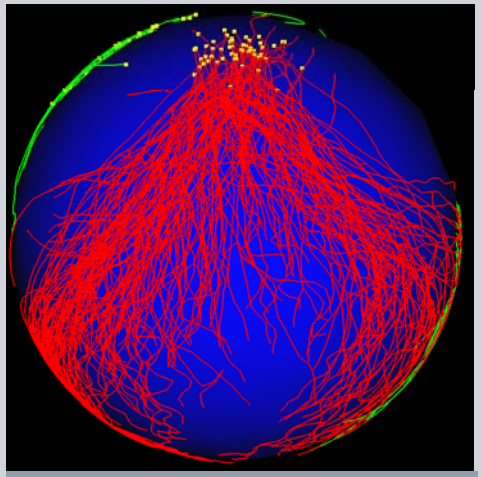
- comparison to TED method missing
  - ➢ previously applied to cerebral vessel matching by Tang, et. al.

Critique - Pros

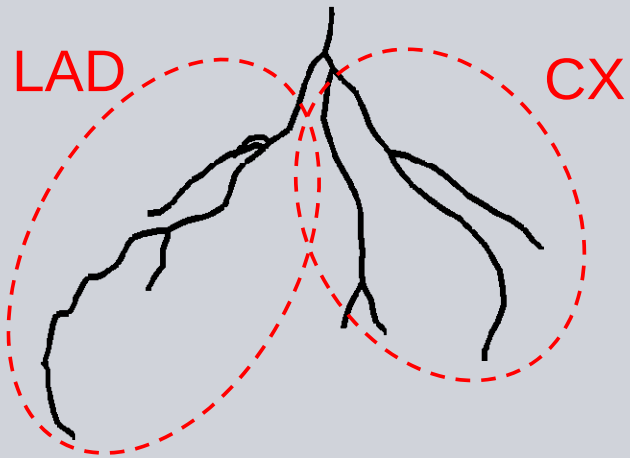
- A novel method that uses both topology and branch geometry
- Unique geodesic metric
  - ➢ suitable for statistical analysis
- Majority vote labeling: simple but effective idea
- Additional attributes can be used
- Presentation of QED to a broader community

Relating Back

- Similar problem: geodesic deformation between trees
  - ➢ 2D coronary centerlines
  - ➢ more resources for handling missing branches
- Prune small branches
- Fix certain main branches, e.g., LAD and CX branches



Left Coronary Trees



- Future work: comparison of TED and QED for branch matching

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References

[1] A. Feragen, P. Lo, V. Gorbunova, M. Nielsen, A. Dirksen, F. Lauze, and M. de Bruijne. An airway tree-shape model for geodesic airway branch labeling. In *Third MICCAI Workshop on Mathematical Foundations of Computational Anatomy*, 2011.

[2] Aasa Feragen, Francois Lauze, Pechin Lo, Marleen de Bruijne, and Mads Nielsen. Geometries on spaces of treelike shapes. In *Proceedings of the 10th Asian conference on Computer vision - Volume Part II*, ACCV'10, pages 160–173, Berlin, Heidelberg, 2011. Springer-Verlag.

[3] W H Tang and Albert C S Chung. Cerebral vascular tree matching of 3d-ra data based on tree edit distance. *Medical Imaging and Augmented Reality*, page 116123, 2006.